LOW LEVEL RADIOACTIVE WASTE: SOURCES, CONTENT, AND SIGNIFICANCE*

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EVERY human activity generates waste. We are just beginning to deal with the monumental problem of household trash. The use of radioactive materials also develops waste. While it is true that, per unit volume, low level radioactive waste may be considered more hazardous than nonradioactive wastes, it is also true that its volumes are smaller. In addition, New York has acted on the low level radioactive waste problem while difficulties with household waste still await solution.

At the present time, low level radioactive waste is being sent to one of three disposal sites throughout the country: Richland, Washington; Barnwell, South Carolina; and Beatty, Nevada. Table I shows the current distribution of New York's waste going to these facilities.[1]

About 10 years ago, these three states objected to receiving all of the nation's low level radioactive waste, and federal elected officials passed legislation that put the burden of disposing of such wastes on each state or on groups of such states, called compacts.[2] New York opted to deal with this waste as an individual state when the New York State Low-Level Radioactive Waste Management Act was passed in 1986.[3] Federal law currently requires that New York have an operating site by January 1993, and that certain milestones be met to prepare for such a site. Failure to meet these milestones or the deadlines for an operating site would be costly to the people of New York since there are financial penalties for noncompliance.

The New York State Low-Level Radioactive Waste Management Act required several steps to ensure that federal requirements are fulfilled. A siting commission was appointed by the governor and given the responsibility for selecting a site and a technology for disposing of low level radioactive

*Presented in a session, Low Level Radioactive Waste. What Are the Facts? as part of a *Symposium on Science and Society: Low Level Radioactive Waste. Controversy and Resolution,* held by the Committee on Public Health of the New York Academy of Medicine and the New York State Department of Health at the Academy September 23, 1988.

TABLE I. CURRENT DISTRIBUTION OF LOW LEVEL RADIOACTIVE WASTE BEING SHIPPED

Facility	Volume (ft^3)	Activity (Curies)
Richland, Washington	30,389 (38.7)*	28 (0.5)
Barnwell, South Carolina	40,900 (52.0)	5,015 (99.2)
Beatty, Nevada	7,335 (9.3)	16 (0.3)

*Percentage of total.

waste. An Advisory Committee was similarly appointed to get public input, to advise the Commission, and to oversee an aggressive public information program. The State Department of Environmental Conservation was given responsibility for publishing regulations for selection of a site and technology. And the New York State Energy Research and Development Authority (NYSERDA) will construct and operate the site.

State law on the management of low level radioactive waste has certain specifications as to how this waste is to be handled. For example, "shallow land burial" is prohibited, the Western New York Nuclear Service center at West Valley cannot be used, and the following three types of disposal technologies must be examined: above ground engineered monitored disposal, underground mined repository disposal, and disposal below ground with engineered barriers.

WHERE DOES LOW LEVEL RADIOACTIVE WASTE ORIGINATE AND HOW MUCH IS INVOLVED?

Table II shows the physical forms of low level radioactive waste generated in the State.[1] In many cases it consists of rubbish used in an environment containing radioactivity. It originates in hospitals, laboratories, industries, and nuclear power plants. NYSERDA has reported that, in New York, 88 medical facilities, 32 industries, 22 academic institutions, and seven nuclear power plants shipped such waste in 1987.[1]

Medical facilities use radioactive isotopes for diagnosis and treatment of disease. There were 7,400,000 diagnostic nuclear medicine procedures conducted in this country in 1982.[4] There were additional therapeutic procedures and millions of radioimmunoassays. Many scientific studies, particularly in modern biology, cannot be conducted without the use of radioactive tracers.[5] Nuclear power plants generate 19% of the electricity in the state. They generate both high and low level radioactive waste. Industrial firms use radioactive materials in devices such as smoke detectors, self-illuminating warning signs, and static eliminators. As a consequence, they generate waste.

TABLE II. LOW LEVEL RADIOACTIVE WASTE FORMS FOR DIFFERENT GENERATORS

Utilities
Spent resins
Evaporator bottoms and concentrated waste
Filter sludges
Dry compressible waste
Irradiated components
Contaminated plant hardware
Academia
Compacted trash or solids
Institutional laboratory or biological waste
Absorbed liquids
Animal carcasses
Medical
Compacted trash or solids
Institutional laboratory or biological waste
Absorbed liquids
Sealed sources
Industrial
Depleted uranium
Compacted trash or solids
Absorbed liquids
Sealed sources
Government
Compacted trash or solids
Contaminated plant hardware
Absorbed liquids

Table III shows the top 10 and the rest of the counties in New York in terms of the volume of radioactive waste generated.[1] The data are also presented in terms of the percentages of the total volume. The activities and the percentages of the total activity are also presented. Most of the low level radioactive waste, in both volume and activity, is generated in the southeastern part of the state and in the Oswego area. This is because all but one of the state's nuclear power plants are located in these two areas. In addition, the Cintichem Corporation, a major manufacturer of the radioiosotopes used in medicine and research, is located in Tuxedo Park, Orange County.

Data for the contribution to the volume and activity of low level radioactive waste from different types of generators for 1987 are presented in Table IV. Most of the volume came from the utilities but there is a sizable medical component. Most of the activity came from the industrial component and nearly all of that activity was generated by the Cintichem Corporation.

TABLE III. LOW LEVEL RADIOACTIVE WASTE SHIPPED BY COUNTY

County	*Number shipping*	*Volume (ft^3)*	*Activity (Curies)*
Oswego	3	27,965 (33.0)*	888 (17.7)*
Westchester	14	16,280 (19.2)	1,134 (22.6)
New York	33	11,886 (14.0)	12 (0.2)
Wayne	1	6,210 (7.3)	201 (4.0)
Orange	4	3,640 (4.3)	2,747 (54.6)
Suffolk	6	2,998 (3.5)	8 (0.2)
Nassau	12	2,228 (2.6)	4 (0.1)
Erie	7	2,069 (2.4)	3 (0.1)
Queens	9	1,957 (2.3)	0.5 (0)
Bronx	6	1,684 (2.0)	5 (0.1)
Other	58	7,894 (9.4)	25 (0.4)

*Percentage of total.

TABLE IV. VOLUME AND ACTIVITY SHIPPED FOR DISPOSAL

Generator	*(ft^3)*	*Curies*
Utilities	51,653 (60.9)*	2,216 (44.1)*
Academia	3,737 (4.4)	14 (0.3)
Medical	20,475 (24.1)	20 (0.4)
Industrial	7,432 (8.8)	2,777 (55.2)
Government	1,515 (1.8)	0.2 (0)

*Percentage of total.

Figure 1 shows the annual volumes of low level radioactive waste generated in New York from 1979 to 1987 and projected volumes to the year 1992. The total annual volume has declined and is expected to level off at about 125,000 cubic feet. Figure 2 depicts the total activity in Curies shipped for disposal from 1979 to 1987 and projected activities to 1992. Again, there has been a reduction in the number of Curies shipped for disposal from a total high of nearly 80,000 in 1979 to about 5,000 in 1987. There is a spike to about 20,000 Curies in the projected activities for 1988 from the utilities but this is expected to level off at approximately 6,000 by 1992. The reduction in both annual volume and annual activity shipped for disposal is due to advances in wate disposal technology. Methods such as compaction and incineration have reduced the volume, while storage for decay (with short-lived radioisotopes) has decreased the activities. Further, many generators have made their operations much cleaner. This has reduced both the volumes and the activities of the waste. The spike in the activity from the utilities may be due to planned maintenance by one or more reactors during this time.

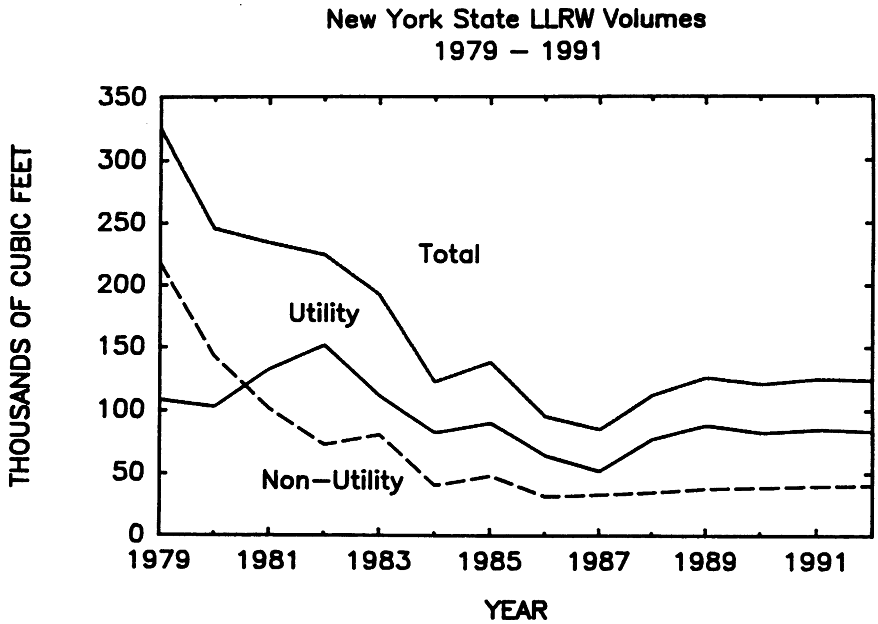

Fig. 1. The volume of low level radioactive waste shipped for disposal from 1979 to 1992. The actual volumes are presented up to 1987. Projected volumes are given from 1988 to 1992.

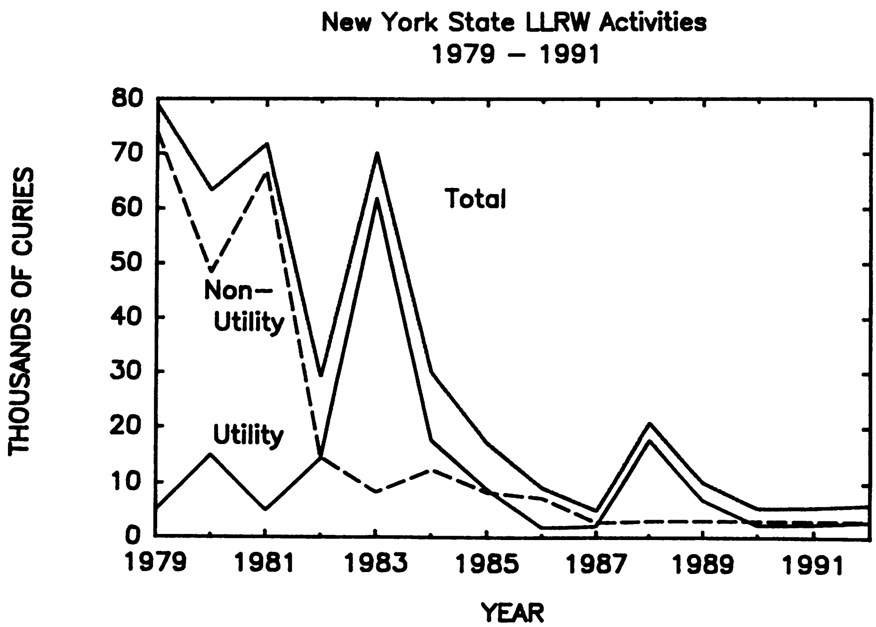

Fig. 2. The activities of low level radioactive waste shipped for disposal from 1979 to 1992. The actual activities are given from 1979 to 1987. Projected activities are presented from 1988 to 1992.

TABLE V. RADIOISOTOPES IN LOW LEVEL RADIOACTIVE WASTE

Nuclide	*Half-life years*	*DEC 30 yr Curies (%)*		*NYSERDA 87 Curies (%)*		*Annual limit on intake Curies*
Group 1						
H-3	12.3	1.55M	(53.2)	39.4	(2.6)	8.1E-2
Fe-55	2.68	450K	(15.5)	----------	----------	8.1E-3
Co-60	5.27	456K	(15.7)	880	(57.6)	1.9E-4
Sr-90	29.0	33.2K	(1.14)	21.5	(1.41)	2.7E-5
Pu-238	87.7	244K	(8.38)	.003	(<0.1)	2.0E-4
Pu-241	14.4	65K	(2.23)	1.19	(<0.1)	8.0E-2
Cm-243	28.5	0.85	(<0.1)	.004	(<0.1)	2.6E-4
Cm-244	18.1	11.8	(<0.1)	1E-6	(<0.1)	6.5E-8
Group 2						
C-14	5.73K	221	(<0.1)	8.24	(0.5)	2.4E-3
Tc-99	213K	1.21	(<0.1)	.188	(<0.1)	2.7E-3
I-129	15.7	2.12	(<0.1)	.088	(<0.1)	5.4E-6
Group 3						
Ni-59	76.4K	323	(<0.1)	1.87	(0.1)	2.4E-2
Ni-63	100	46.1K	(1.58)	188	(12.3)	8.1E-3
Nb-94	20K	4.43	(<0.1)	.05	(<0.1)	1.1E-3
Cs-135	3M	1.21	(<0.1)	----------	----------	8.1E-4
Cs-137	30.2	50.9K	(1.75)	369	(24.1)	1.1E-4
U-234	244K	18.9	(<0.1)	----------	----------	1.1E-5
U-235	704M	0.71	(<0.1)	.01	(<0.1)	1.4E-5
U-238	4.47B	3.2	(<0.1)	.02	(<0.1)	1.4E-5
Np-237	2.14M	2E-5	(<0.1)	----------	----------	8.1E-8
Pu-239	6.56K	3.23K	(0.11)	.022	(<0.1)	5.4E-6
Pu-242	376K	7.06	(<0.1)	6E-7	(<0.1)	8.1E-6
Am-241	432	12.5K	(0.43)	.012	(<0.1)	1.4E-6
Am-243	7.37K	.97	(<0.1)	----------	----------	1.4E-6
Group 4						
C1-36	308K	----------	----------	8E-3	(<0.1)	1.6E-3
Eu-152	12.7	----------	----------	9E-4	(<0.1)	8.1E-4
Kr-85	10.8	----------	----------	4E-3	(<0.1)	1.3E-4
Pb-210	20.4	----------	----------	1E-3	(<0.1)	5.4E-7
Ra-226	1.6K	----------	----------	.39	(<0.1)	1.9E-6
Th-232	14.1B	----------	----------	4E-3	(<0.1)	8.1E-6
Other						
TU	---------	----------	----------	18.4	(1.2)	--------------

Note: K = thousand, M = million, B = billion

WHICH RADIOISOTOPES ARE INCLUDED IN LOW LEVEL RADIOACTIVE WASTE?

Radioisotopes included in low level radioactive waste are given in Table V. Two sets of data are presented. The first set is taken from the Department of Environmental Conservation Dose Assessment Supplement to the environmental impact statement for the regulations for waste disposal facilities.[6] This information is, in turn, taken from the draft environmental impact statement for the federal regulations on low level radioactive waste.[7] These numbers are based on a total disposal volume of 217 thousand cubic meters over a 30 year period. This is equivalent to 7.66 million cubic feet and an average of 255 thousand cubic feet per year, or about twice the annual volume projected for the state. The second set of data is taken from the latest NYSERDA report for 1987.[1] Both sets of data were put into the same table to allow comparison of the projection of the Nuclear Regulatory Commission with what is currently shipped from New York for disposal. Some differences are apparent, especially when considering group 4, which consists of radioisotopes currently included in New York's but not in the Nuclear Regulatory Commission's projection. This is a point that will be considered in the design and siting of New York's facility.

The half-lives of the radioisotopes are presented in the second column. The Annual Limit on Intake is given in the last column. This is the activity for each radionuclide that is estimated to give a lifetime dose of 5 rem to an adult man. It is given here as an index of the hazard of each radioisotope. The smaller the index, the greater the hazard.

Many radionuclides are generated that are not included in Table V. For example, medical institutions develop wastes containing I-131 and P-32 with half-lives of 8 and 14 days, respectively. To save money on waste disposal, institutions store such wastes until they have decayed to background levels.

The radioisotopes listed in Table V have long half-lives, and will be in the disposal facility for a long time. As long as they are so retained, they will pose no hazard to the population. It is prudent, however, to estimate how much leakage may take place under normal and abnormal circumstances. Computer modeling is used to make such estimates over very long periods of time.

It is also important to recognize that low level radioactive wastes are placed in containers according to their hazard. The Nuclear Regulatory Commission has defined three classes of such waste: A, B, and C.[2] Class A waste must meet certain minimum requirements. Classes B and C must meet the same requirements but must also be in a form which ensures stability after disposal. In the Dose Assessment Supplement, the Department of Environmental Conservation assumes the Class A is compacted waste and that Classes B and C are solidified in cement to reduce leakage from the two more stable wastes.[6] Table VI lists the amounts of these three classes in 1987.[1] It may be noticed that Class A contains most of the volume but that Class B has most of the activity.

TABLE VI. CLASSES OF LOW LEVEL RADIOACTIVE WASTE SHIPPED IN 1987

	Class A		*Class B*		*Class C*	
Generator	*ft³*	*Curies*	*ft³*	*Curies*	*ft³*	*Curies*
Utilities	49.6K*	981.3	1.58K	600.6	441	634.1
Academia	3.74K	13.9	0	0	0	0
Medical	20.4K	19.4	60	0.3	60	0.3
Industrial	6.40K	29.7	1.03K	2.75K	0	0
Government	1.51K	0.2	0	0	0	0

*K = thousands.

It should be recognized that the half-life of a given radioisotope is only one factor which determines the risk from that isotope. Among the factors are the radiations emitted, the metabolism of the chemical compound involved, the method of preparing the waste, the integrity of the waste disposal facility, the geology of the waste disposal site, the leakage of ground water into the disposal facility, the leachability of the radionuclide from the waste package into the ground water and into the public domain, and the fate of the radioactivity when it enters the environment. And, with regard to the last point, it is important to know whether the radionuclide enters the food chain or drinking water.

What Doses Of Radiation Will Be Delivered To The Public And How Will They Compare With Doses Already Being Received?

The laws limit the doses from a low level radioactive waste facility to 25 mrem/yr to the whole body, 75 mrem/yr to the thyroid and 25 mrem/yr to any other organ of any member of the public. The term mrem/yr is really a dose equivalent rate. It is easiest to compare these numbers with other dose rates which will be done later.

The concentrations of radioactive isotopes that enter the public domain will depend upon the method used and the site chosen. At the present time, only generic modeling may be made. Results taken from the Dose Assessment Supplement will be used as an example.[6] This model gives doses to the public higher than other studies and are, therefore, considered to be conservative.

The Department of Environmental Conservation categorized the wastes into three groups.[6] Two factors were considered: the half-life of the radioisotopes and, if and when it leaches out of the facility, its transit time in the ground water. Calculations were made for Group 1 for 3,000 years at 10 year steps, for Group 2 for 24,000 years at 80 year steps, and for Group 3 for 300,000 years at 1,000 year steps. These are the first three groups listed in Table V.

The Department considered the three methods mentioned in the state law: above ground vault, below ground vault, and mined repository. They divided the state into six physiographic provinces. Three of these are not considered to be suitable for a disposal facility.

Table VII summarizes the results of the Department's study, and gives the peak annual whole-body and thyroid dose rates and the years at which these dose rates occur. It may be seen that, in this generic study, methods and geologic areas can be matched which meet the legal requirements. Care must be taken in the selection process because there are also combinations of method and geological area that result in doses higher than the legal limits. From this study it appears that any of the three methods would be acceptable in province IV and that the deep mined repository would also be acceptable in province V. Province IV lies mainly along the southern tier of the state with a pocket in the north central part of the state. Province V covers the northern and western parts of the state. Again, these are generic studies and any final selection must deal with specific sites and areas.

The dose rates shown in Table VII are due to the three radionuclides in group 2 of Table V even though they account for less than 0.01% of the initial activity. These are long-lived and are relatively mobile in the ground water. Nearly all of the dose rate which exceeds the performance objective for the facility is due to I-129.

There are problems with this dose estimate of I-129. Remember that the model uses Nuclear Regulatory Commission numbers for the volume and activity found in the disposal facility (column 3 in Table V) and that this is based on an annual volume of low level radioactive waste twice that estimated for New York.

I-129 has a very long half-life (15.7 million years). For the amounts of I-129 in low level radioactive waste, it has a very small activity. In fact, most of the time activity is below the lower limit of detection of instruments used to measure it. For example, the lower limit of detection may be 1 picoCurie, waste involved may only contain 0.01 picoCurie, and its activity cannot be distinguished from background. In the interest of conservatism, the generator will label the waste as containing 1 picoCurie, 100 times the real activity. It is estimated that some samples are as much as 100,000 times lower than the reported activity for this isotope. These factors serve to overestimate the true population dose to the public from this isotope, and will have to be considered in the final analysis.

In addition, the National Council on Radiation Protection and Measurements has been unable to find any evidence that I-129 has caused cancer in

TABLE VII. DEPARTMENT OF ENVIRONMENTAL CONSERVATION PEAK ANNUAL DOSE RATES FOR LOW LEVEL RADIOACTIVE WASTE FACILITIES

Method	*Province*	*Whole-body mrem/yr*		*Thyroid mrem/yr*	
Above ground vault	II	20	(1,680)	630	(1,680)
Above ground vault	IV	1	(1,440)	31	(1,360)
Above ground vault	V	39	(2,000)	1300	(2,000)
Below ground vault	II	9	(1,840)	290	(1,840)
Below ground vault	IV	2	(7,840)	59	(7,920)
Below ground vault	V	50	(2,160)	1,600	(2,080)
Mined repository	II	15	(14.6K)	470	(14.6K)
Mined repository	IV	7E-3	(1.4M)	0.2	(1.4M)
Mined repository	V	0.01	(1.1M)	4	(1.1M)

Numbers in parentheses are the years after closure of the facility at which the peak dose rate appears. K = thousands, M = millions.

TABLE VIII. ANNUAL AVERAGE WHOLE BODY DOSE EQUIVALENTS RECEIVED BY INDIVIDUALS IN THE U.S. FROM VARIOUS SOURCES

Natural sources	*Effective dose equivalent (mrem/yr)*
Inhaled radon daughters	200
Cosmic radiation	30
Terrestrial radiation	30
Internal radionuclides	40
Man-Made Sources	
Medical, dental x rays	39
Nuclear medicine	14
Consumer products	9
Other	<3
Rounded total	360

either man or experimental animals, a finding they attribute to the relatively large mass of the iodine needed to produce a meaningful dose and the low dose rate that results when the isotope is taken into the thyroid gland.[8] The Council concludes "....that I-129 does not pose a meaningful threat of thyroid carcinogenesis in people."

It is useful to compare these projected annual dose rates with those currently being received by the American population. Table VIII gives this information taken from a Council report.[4] The average effective whole body dose equivalent is 360 mrem/yr, at least seven times higher than any of the whole body doses listed in Table VII for a generic facility in New York. But that is not the worst of it. The numbers presented in Table VIII are averages.

Numbers of people in this state are being exposed to dose rates much larger than this. Consider the problem of indoor radon, the largest contributor listed in Table VIII. According to a NYSERDA news release in November 1987, the concentration of indoor radon measured in this state ranged from 0 to 38.3 picoCuries/Liter of room air.[9] This results in a range of effective whole body dose equivalents of from 0 to 9,600 mrem/yr (see method of calculation in Table I in reference 5). NYSERDA's data on indoor radon allows the interpretation that more than 144,000 people in this state are currently receiving greater than 1,000 mrem/yr from indoor radon in their own homes. This is 20 times higher than the estimated whole body dose rates listed in Table VII for a low level radioactive waste facility.

HOW MUCH WILL ALL OF THIS COST?

It is impossible to estimate the cost of a low level radioactive waste facility at the present time. However, the federal Department of Energy has published brochures which list six methods of disposing of this waste, their projected costs, and the maximum projected doses to members of the public.[10] Those data are presented in Table IX. This information is based in all cases on an annual average volume of 235,000 cubic feet, twice that projected for New York at the present time. The first column gives the method and a footnote telling what each acronym means. The second column shows the cost in millions of dollars for the facility. The third column shows the maximum dose rate to a person from this site. These dose rates are much lower than those predicted by the Department of Environmental Conservation report, a point noted by it.[6] The point is that enormous sums of money are proposed for these facilities. The question is whether these expenditures improve public health and safety. There is evidence that we spend far more money on radiological protection than we spend protecting ourselves from other activities.[11]

TABLE IX. COSTS OF LOW LEVEL RADIOACTIVE WASTE
(COSTS IN MILLIONS OF DOLLARS)

Method	*Cost*	*Dose Rate mrem/yr*
Shallow land disposal	231	8
Below ground vault	350	4
Modular concrete cannister disposal	350	7
Intermediate depth disposal	245	6
Above ground vault	427	34
Earth mounded concrete bunker	483	4

CONCLUSIONS

A low level radioactive waste facility can be built within the rules and regulations set by the State Department of Environmental Conservation. The exception to this is that, due to the late start in forming the Siting Commission, there will be a delay in getting a site and method certified. It is anticipated that, if all goes well, the necessary certifications will take place by mid 1991. NYSERDA can then be expected to start construction sometime in the spring of 1993 instead of January of that year.

The public health and safety will be protected. Within the guidelines set by the New York state Low-Level Waste Management Act, the process will be conducted in a scientific manner while fully informing the public and seeking the opinions and choices of the people. However, it is also felt that the costs of disposing of low level radioactive waste should be an important consideration, especially when these costs may be diverted from other enterprises that also involve the public health and safety, such as health care and biomedical research.

REFERENCES

1. Blood, P., Maryanopolis, L., Salame-Alfie, A., and Spath, J.: *1987 New York Low-Level Radioactive Waste Status Report*. Albany, NY, New York State Energy Research and Development Authority, 1988.
2. 96th U.S. Congress: *Low-Level Radioactive Waste Policy Act*. Public Law 96-573. Washington, D.C., 1980.
3. New York State Senate and Assembly: *Low-Level Radioactive Waste—Disposal Facilities—Siting Commission—Advisory Committee—Information Program*. Chapter 673. Albany, NY, 1986.
4. National Council on Radiation Protection and Measurements: *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 93. Washington, D.C., 1987.
5. Darnell, J., Lodish, H., and Baltimore, D.: *Molecular Cell Biology*. New York, Scientific American Books, 1986, p. 222.
6. New York State Department of Environmental Conservation: Supplement to the July 1987 Draft Environmental Impact Statement for Promulgation of 6 NYCRR Part 382: Regulations for Low-Level Radioactive Waste Disposal Facilities; Modelling and Dose Assessment of Alternative Low-Level Radioactive Waste Disposal Methods In New York State. Albany, NY, 1988.
7. United States Nuclear Regulatory Commission: *Draft Environmental Impact Statement on 10CFR Part 61*. NUREG-0782. Washington, D.C., 1981.
8. National Council on Radiation Protection and Measurements: *Induction of Thyroid Cancer by Ionizing Radiation*. NCRP Report No. 80. Washington, D.C., 1985.
9. New York State Energy Research and Development Authority: News release on indoor radon in New York State. November 4, 1987.
10. United States Department of Energy: A series of brochures on the disposal of low-level radioactive waste. Disposal Site: BP504-3-0687-.5M-T; Shallow Land Disposal: BP504-7-0687-.5M-T. Below Ground Vault: BP504-2-0687-.5M-T; Modular Concrete Canister Disposal: BP504-6-0687-.5M-T; Intermediate Depth Disposal: BP504-5-0687-.5M-T; Above Ground Vault: BP504-1-0687-.5M-T; Earth Mounded Concrete Bunker: BP504-4-0687-.5M-T.
11. Cohen, B.L.: Society's valuation of life saving in radiation protection and other contexts. *Health Phys. 38:*33-51, 1980.